MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2016; 22: 1329-1333
DOI: 10.12659/MSM.898164

Received: 2016.02.22
Accepted: 2016.04.01
Published: 2016.04.20

Assessing Safety of Pneumatic Tube System (PTS) for Patients with Very Low Hematologic Parameters

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Source of support: Scientific Research Projects Service of Inonu University

Background: Preventive interventions save lives during the process of chemotherapy for hematologic malignancies, when a hematology laboratory can ensure accurate results. The use of a pneumatic tube system (PTS) is associated with measurement errors and unnecessary transfusions. The aim of this study was to evaluate pre-analytical errors associated with transportation method (PTS versus hand-delivered) and to investigate whether there are unnecessary transfusion events in pancytopenia leukemia patients with very low hematological parameters.

Material/Methods: A total of 140 paired blood collections were performed for hemogram and biochemistry assays. Paired EDTA and serum gel blood samples were collected from 58 cases with acute leukemia on different days. For each pair, one sample was hand-delivered by a courier (Group 1) while the other sample was transported through a PTS (Group 2).

Results: The hand-delivered method showed that some platelet transfusions were unnecessary for different thrombocyte cut-off values. Calculated unnecessary platelet (PLT) transfusion ratios when using PTS (PLT <30×10^3/µL, 16.3%; PLT <25×10^3/µL, 16.4%; PLT <20×10^3/µL, 80.3%; PLT <15×10^3/µL, 48.6%; and PLT <10×10^3/µL, 150.0%) were found to be statistically significant (p=0.002, p=0.046, p<0.000, p=0.028, and p<0.000, respectively). In contrast, for RBC transfusion ratios, although the ratios were high in Group 2, we found no significant difference between the two groups; (HGB <8.0 g/dL, 23.3%; HGB <9.0 g/dL, 25.0%, HGB<10.0 g/dL, 19.3%) and (p=0.002, p=0.085, p<0.160, and p=0.235, respectively).

Conclusions: Although our results cannot be universally applied, physicians should be careful, skeptical, and suspicious of transfusion decisions in hematology clinics and consider potential analytical and pre-analytical errors in cases of severe cytopenia when using PTS.

MeSH Keywords: Blood Component Transfusion • Leukemia, Myeloid, Acute • Transportation

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Background

Leukemia and its treatment modalities lead to bone marrow insufficiency. Therefore, during leukemia treatment, platelet (PLT) and red blood cell (RBC) transfusions are frequently required due to anemia and thrombocytopenia. Although improved availability of PLT for transfusion has largely eliminated bleeding [1], reliable PLT levels may not always be obtained. Patient factors that decrease post-transfusion PLT responses are male gender, splenomegaly, bleeding, fever, infection, disseminated intravascular coagulation, increasing height and weight, or receiving heparin. Also, alloimmunization due to lymphocytotoxin antibodies and ≥2 prior pregnancies are associated with this phenomenon. An increasing number of PLT transfusions may induce alloimmunization [2]. Hemolytic and non-hemolytic life-threatening complications (i.e., graft-versus-host disease) may appear in patients with impaired immune systems. A large number of RBC transfusions can also cause iron overload [3]. Avoiding excessive transfusions may also reduce PLT alloimmunization and transfusion complications in the course of disease. Furthermore, leukemia is associated with unacceptable low levels of white blood cells. Granulocyte-colony stimulating factors (G-CSF) may be required. Physicians may be misled by insufficient or unreliabile laboratory results [4]. Reliability of laboratory results depends on avoidance of inaccuracies in preanalytical phases. There are several essential steps in the preanalytical phase, including the relevance of a test request and the correct collection, handling, transport, and storage of the specimen [5]. Maintenance of the optimal conditions for sample transport is important. The pneumatic tube system (PTS) is commonly used to transport blood samples rapidly from hospital inpatient services to the laboratory. If PTS is used properly, some benefits, such as cost efficiency, time efficiency, reduced risk of sample loss, and reduced manpower requirements may be obtained. However, PTS transportation is also associated with some risks, such as *in vitro* hemolysis and aberrant results for plasma lactate dehydrogenase (LD) [6,7]. These errors are particularly more likely for leukemic patients with fragile leukocyte membranes [8]. The PTS effects are associated with transportation speed, acceleration and deceleration, spin times at corners, distance to station, and a lack of cushioning [9–11]. The aim of this prospective study was to assess the potential influence of the use of a PTS for routine hematological tests and determine whether PTS interferes with complete blood cell counts (CBC) and causes unnecessary transfusions.

Material and Method

Study design

We conducted this prospective cross-sectional study in August 2013 in the Training and Research Hospital. The study involved 58 pancytopenia cases with acute leukemia (45 males and 13 females; median age, 46 years; range 28–56 years). We submitted this study to the Internal Review Board and received approval from the local Human Research Ethics Committee. Financial support was received from the Scientific Research Projects Service of Inonu University. All volunteers provided informed consent.

Collection of blood samples

Blood samples were collected from donors between 9 a.m. and 10 a.m. during a one-week period, after a 12-hour fast. All samples were drawn by the same expert phlebotomist nurse who adhered to the recommendations of the Clinical Laboratory Institute (CLSI) [12]. Blood samples were collected from each donor into two pairs of tubes, for a total of four tubes per patient. The blood was collected into 2.0 mL dipotassium (K_2) ethylene diamine tetraacetic acid (EDTA) vacuum tubes for complete blood cell count (BD Vacutainer, BD Plymouth, UK). For biochemical assay to evaluate lactate dehydrogenase (LD), aspartate aminotransferase (AST), alanine aminotransferase (ALT), potassium (K), total, conjugated, and unconjugated bilirubin (TB, CB, and UB), the blood was collected into gel-tubes.

Hand-delivered transport procedure

Diagnostic blood specimens were kept in vertical, closure-up position, and hand-carried by the same laboratory staff in a biohazard container at room temperature (20°C) from hematology services to the laboratory. The mean transport duration was nine minutes by walking and escalator from the ninth floor to the ground floor.

PTS transport procedure

The PTS used in our hospital (Pneumatic Tube Systems MP10000, Version 2.3.0; Sumetzberger GmbH, Vienna, Austria) has four subsystems, 43 stations, four corners, and a constant speed of 6 m/second. Our PTS carriers are 160 mm in diameter and 440 mm in length. The carriers are made from plastic and contain sponge-rubber to protect the samples during PTS transportation. In this study, we used the hematology service PTS station on the hospital's top floor, which is the furthest distance from the laboratory (185 meters).

Statistical analysis

Distributional properties of continuous variables were performed using Anderson Darling Test. Mean and standard deviation were used as descriptive statistics for normally distributed variables, while medians (minimum-maximum) were used as descriptive statistics for non-normally distributed variables. Normally distributed variables were compared using one-way

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Table 1. Patient characteristics.

Features	Patients
Age (years)	46 (28–56)*
Gender (male/female)	45 (78%)/13 (22%)#
Leukemia type	
AML	48 (83%)#
ALL	10 (17%)#

AML – acute myeloblastic leukemia; ALL – acute lymphoblastic leukemia. * Median (range); # Number of patients (percentage).

ANOVA for groups, and the least significantly differences (LSD) test was employed as a post-hoc test. Non-normally distributed variables were compared using Kruskal-Wallis test and Wilcoxon Rank Sum test was used as a post-hoc test. Different transfusion cutoff values were defined for RBC and PLT in the clinic. Then odds ratios (OR) test was used to analyze unnecessary transfusion.

Results

The patient characteristics, including age, gender, and leukemia type, are summarized in Table 1. The comparison of results between blood samples delivered to the laboratory by PTS and courier are shown in Table 2, which contains complete blood counts and biochemical parameters that might be affected by different transportation types. Statistically no significant differences were observed in different cut-off values for HGB levels. PTS suggested a number of 10-unit RBC transfusions, while hand-delivered transportation suggested three transfusions, for a cut-off level of 8.0 g/dL. For this cut-off value, however, the unnecessary transfusion ratio was 23.3% in PTS; no significant difference was found (p=0.085) due to

Table 2. Descriptive statistics of blood analysis results for two types of transportation.

	Group 1	Group 2	*P*
WBC (×10³/μL)#	0.800 (0.100–7.800)	0.700 (0.100–7.700)	0.021
RBC (×10³/μL)*	3.012±0.278	2.981±0.282	**0.000**
HGB (g/dL)#	9.300 (7.200–10.900)	9.100 (7.000–10.300)	**0.000**
HCT (%)*	27.09±2.28	26.56±2.11	**0.000**
MCV (fL)#	89.00 (80.30–106.50)	88.80 (81.10–106.70)	0.29
MCH (pg)#	29.70 (26.80–33.70)	29.70 (27.00–32.60)	0.96
MCHC (g/dL)#	30.10 (26.80–33.70)	30.10 (27.00–33.70)	**0.000**
RDW#	15.0 (12.0–25.3)	15.0 (12.1–27.1)	0.94
PLT (×10³/μL)#	22.0 (2.0–64)	17.0 (9.0–63.0)	**0.000**
MPV (fL)#	7.85 (5.9–10.5)	7.8 (5.9–11.6)	0.81
LD (U/L)#	168.0 (56.0–815.0)	189.5 (60.0–847.0)	**0.000**
TB (mg/dL)#	0.97 (0.22–21.34)	0.97 (0.09–21.35)	0.70
CB (mg/dL)#	0.43 (0.13–16.5)	0.44 (0.14–16.48)	0.76
UB (mg/dL)#	0.52 (0.10–4.97)	0.49 (0.08–4.84)	**0.000**
AST (U/L)#	13.0 (4.0–82.0)	16.0 (4.0–82.0)	**0.000**
ALT (U/L)#	21.0 (3.0–158.0)	22.0 (6.0–159.0)	0.15
Potassium (K) (mmol/L)#	3.7 (2.3–6.8)	3.9 (2.5–6.9)	**0.000**

Group 1 – Hand delivered system; Group 2 – PTS delivered. SI – International System of Units; PTS – pneumatic tube system; WBC – white blood cell; RBC – red blood cell; HBG – hemoglobin; HTC – hematocrit; MCV – mean corpuscular volume; MCH – mean corpuscular; MCHC – mean corpuscular hemoglobin concentration; RDW – red cell distribution width; PLT – platelet; MPV – mean platelet volume; LD – lactate dehydrogenase; TB – total bilirubin; CB – conjugated bilirubin; UB – unconjugated bilirubin; AST – aspartate aminotransferase; ALT – alanine aminotransferase. * Trait is normally distributed; mean (±SD); P value obtained from paired Student's t-test. # Trait is non-normally distributed; median (min.–max.); P-value obtained from Wilcoxon signed-rank test.

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Table 3. Transfusion suggestions for different transport types (P values obtained from odds ratio test).

Putative cut-off values for transfusion requirement	Group 1(α)	Group 2(β)	Δ	% Δ/α	*P*
HGB <8.0 g/dL§	3	10	7	233.3	0.085
HGB <9.0 g/dL§	44	55	11	25.0	0.160
HGB <10.0 g/dL§	114	136	22	19.3	0.313
PLT <30×10³/μL#	110	128	18	16.3	**0.002**
PLT <25×10³/μL#	91	106	15	16.4	**0.046**
PLT <20×10³/μL#	56	101	45	80.3	**0.000**
PLT <15×10³/μL#	35	52	17	48.6	**0.028**
PLT <10×10³/μL#	16	40	24	150.0	**0.000**

HGB – haemoglobin; PLT – platelet; PTS – pneumatic tube system. § Red blood cell suspension transfusion suggestions for the cut off value. # Platelet suspension transfusion suggestions for the cut off value. Group1 (α) – number of patients who required transfusion in hand delivered system; Group2 (β) – number of patients who required transfusion in PTS delivered. Δ – α–β (the differences between number of patients who required transfusion in hand delivered system and PTS); % Δ/α – ratio of unnecessary transfusion number. * Obtained from odds ratio test.

small sample size. Similarly, PTS indicated high numbers of RBC transfusion units for different assigned HGB cut-off values, but there was no significant difference between groups. For PLT values, transfusion ratios were high and unnecessary transfusion ratios were found to be significantly different for all of the cut-off values in the PTS group. For different HGB and PLT cut-off values, the transfusion indications of the two transportation types is summarized in Table 3.

Discussion

The pneumatic tube system (PTS) has become a widely used method of transport in hospitals. PTS is a cost-effective method and minimizes delivery delays of patient samples to the laboratory [5,11]. Published studies showing the potential impact of PTS on different test parameters have identified differences among different types of PTSs. Although the effects of PTS on laboratory results have been well documented in the literature, this is the first report to assess the safety of PTS for patients with very low hematologic parameters. However, eight major studies have investigated the effects of PTS on complete blood count [11,13–19]. In a recent study, PTS and manual transportation were investigated using 50 healthy volunteers' blood samples; no clinical impact or statistically significant differences were observed between the two different transport procedures [19]. Although our results are comparable with published literature, the other studies did not look at patient groups with severe cytopenia or investigate whether or not PTS affects the transfusion requirement. However, other study samples were exposed to forces of pressure during transport (i.e., changes in air pressure, shaking, vibrations, and sudden accelerations and decelerations) [11]. WBC count errors in PTS may be affected by fragile leukocyte membranes. Dastych et al. showed that leukemia causes pseudohyperkalemia and was associated with *in vitro* cellular lysis [8]. Other research has considered how the PTS affects leukemic cells physically [20]. In our study, high LD, AST, and potassium levels in Group 2 (the PTS group) support this consideration. Exposure to physical forces may also have caused reduced PLT count in the PTS group. In the literature, there are publications that support this suggestion. In one study, PTS transport had a significant influence on PLT function [21]. Consistent with this, Hübner et al. showed the effect of a PTS on PLT aggregation using optical aggregometry and the PFA-100 [22]. It is possible that the fast spins at the offsets (pipe corners) may cause PLTs to position closer with each other due to centrifugal force, so that the number of corners may be associated with reduced PLT levels. Also, several factors, such as the amount of blood in the tube, the type of PTS, the distance from collection of the sample to the laboratory, and the cushioning of the transport container, could affect the cell counts [18]. Consequently, further studies should be planned for evaluating the impact of PTS on routine laboratory testing (i.e., coagulation tests) in hematology centers.

Conclusions

In our study, we found that the PTS had a potential effect on routine hematological testing. Blood cell counts in patients with leukemia may be altered by the use of PTS transportation. Because each extra transfusion leads to an increase

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in cost and transfusion-related complications, unnecessary transfusions should be avoided. Physicians should be careful, skeptical, and consider potential analytical and pre-analytical errors in cases of severe cytopenia when using PTS.

References:

1. Schiffer CA, Aisner J, Wiernik PH: Frozen autologous platelet transfusion for patients with leukemia. N Engl J Med, 1978; 299: 7–12
2. Slichter SJ, Davis K, Enright H et al: Factors affecting posttransfusion platelet increments, platelet refractoriness, and platelet transfusion intervals in thrombocytopenic patients. Blood; 2005; 105: 4106–14
3, Johnson P, Signorelli J, Pizzolato P: Acute myelogenous leukemia. Report of a case receiving 214 blood transfusions and with the development of hemosiderosis. New Orleans Med Surg J, 1951; 103: 393–97
4. Ypma PF, van der Meer PF, Heddle NM et al: A study protocol for a randomised controlled trial evaluating clinical effects of platelet transfusion products: The Pathogen Reduction Evaluation and Predictive Analytical Rating Score (PREPAReS) trial. BMJ Open, 2016; 6: e010156
5. Lima-Oliveira G, Lippi G, Salvagno GL et al: Impact of the phlebotomy training based on CLSI/NCCLS H03-A6-procedures for the collection of diagnostic blood specimens by venipuncture. Biochem Med, 2012; 22: 342–51
6. Gomez-Rioja R, Fernandez-Calle P, Alcaide MJ et al: Interindividual variability of hemolysis in plasma samples during pneumatic tube system transport. Clin Chem Lab Med, 2013; 51: e231–33
7. Strubi-Vuillaume I, Carlier V, Obeuf C et al: Gentle blood aspiration and tube cushioning reduce pneumatic tube system interference in lactate dehydrogenase assays. Ann Clin Biochem, 2016; 53(Pt 2): 295–97
8. Dastych M, Čermáková Z: Pseudohyperkalaemia in leukaemic patients: The effect of test tube type and form of transport to the laboratory. Ann Clin Biochem, 2014; 51: 110–13
9. Plebani M, Zaninotto M: Pneumatic tube delivery systems for patient samples: Evidence of quality and quality of evidence. Clin Chem Lab Med, 2011; 49: 1245–46
10. Kavsak PA, Mansour M, Wang L et al: Assessing pneumatic tube systems with patient-specific populations and laboratory-derived criteria, Clin Chem, 2012; 58: 792–95
11. Koçak EF, Yöntem M, Yücel Ö et al: The effects of transport by pneumatic tube system on blood cell count, erythrocyte sedimentation and coagulation tests. Biochem Med (Zagreb), 2013; 23: 206–10
12. Lima-Oliveira G, Lippi G, Salvagno GL et al: Preanalytical management: serum vacuum tubes validation for routine clinical chemistry. Biochem Med, 2012; 22: 180–86
13. Keshgegian A, Bull G: Evaluation of a soft-handling computerized pneumatic tube specimen delivery system. Effects on analytical results and turnaround time. Am J Clin Pathol, 1992; 97: 535–40
14. Sodi R, Darn SM, Stott A: Pneumatic tube system induced haemolysis: Assessing sample type susceptibility to haemolysis. Ann Clin Biochem, 2004; 41: 237–40
15. Weaver D, Miller D, Leventhal E, Tropeano V: Evaluation of a computer-directed pneumatic-tube system for pneumatic transport of blood specimens. Am J Clin Pathol, 1978; 70: 400–5
16. Kratz A, Salem RO, Van Cott EM: Effects of a pneumatic tube system on routine and novel hematology and coagulation parameters in healthy volunteers. Arch Pathol Lab Med, 2007; 131: 293–96
17. Wallin O, Söderberg J, Grankvist K et al: Preanalytical effects of pneumatic tube transport on routine haematology, coagulation parameters, platelet function and global coagulation. Clin Chem Lab Med, 2008; 46: 1443–49
18. Sari I, Arslan A, Ozlu C et al: The effect of pneumatic tube system on complete blood count parameters and thrombocyte donation in healthy donors. Transfus Apher Sci, 2012; 47: 81–83
19. Lima-Oliveira G, Lippi G, Salvagno G et al: Management of preanalytical phase for routine hematological testing: is the pneumatic tube system a source of laboratory variability or an important facility tool? Int J Lab Hematol, 2014; 36: e37–e40
20. Guiheneuf R, Vuillaume I, Mangalaboyi J et al: Pneumatic transport is critical for leukaemic patients with major leukocytosis: What precautions to measure lactate dehydrogenase, potassium and aspartate aminotransferase? Ann Clin Biochem, 2010; 47: 94–96
21. Bolliger D, Seeberger MD, Tanaka KA et al: Pre-analytical effects of pneumatic tube transport on impedance platelet aggregometry. Platelets, 2009; 20: 458–65
22. Hübner U, Böckel-Frohnhöfer N, Hummel B, Geisel J: The effect of a pneumatic tube transport system on platelet aggregation using optical aggregometry and the PFA-100. Clin Lab, 2009; 56: 59–64

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